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Track the maximum power of a photovoltaic to control a cascade five-level inverter a single-phase grid-connected with a fuzzy logic control

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Article Info	ABSTRACT
	This research presents tracking the maximum power of a photovoltaic to control a five-level inverter, a cascade type connecting a single-phase grid-connected system with a fuzzy logic control model. Maximum power tracking control In this research, the principle of controlling the maximum current amplitude of the photovoltaic multiplied by the sine signal per unit that used as a reference current compared to the grid current. Signal comparison with the PID controller allows the creation of five levels of PWM of cascade control of five-level inverter connects single-phase grids. The results of the simulation test using the program MATLAB/Simulink to compare with the generated prototype found that the fuzzy logic principle was used to control the maximum power tracking conditions of the P&O method, when the amount of radiation light intensity decreases suddenly, making it possible to track the maximum power of the photovoltaic. Also, when the inverter connected to the grid by controlling the power angle to compare results between the simulation and the prototype-found that the current flowing into the grid increases according to the power angle control. Resulting in a nearby waveform, sine wave and an out of phase angle to the grid voltage because the system is in the inverter mode, and the harmonic spectrum of the grid currently has total harmonic distortion (THD) is reduced as an indication of the proposed system can be developed and applications.

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1. INTRODUCTION

From general research, solar energy control presented with many different methods, such as perturb and observe control (P&O), incremental conductance (INC), fuzzy logic control (FLC) and genetic (GA), which are independent, isolated alone, to supply that voltage to the circuit boost converter or buck-boost converter and to supply for loading alone. However, encountered constant power control problems that were quite difficult and at the same time if being paid into the grid or supplying non-linear loads, needing the best principles and control methods [1-4]. For the proposed research, the simulation and construction of the maximum power tracking prototype. Using the principle of controlling the maximum current amplitude of the solar cell multiplied by the sinusoidal signal per unit that is used as the reference sine current compared to the grid current through PID to control a cascade five-level inverter a single-phase grid-connected with a fuzzy logic control which is different from the one mentioned above.

Models and components of the PV system require the use of the highest point tracking technique

(MPPT) to track the maximum power under different conditions. The proposed MPPT algorithm observation (P&O) and increased conductivity (IC). All so, under sudden radiation and temperature changes in the PV system with the help of a new adaptive controller that withstand these heavy disturbances. The results from the comparison of the two techniques, the characteristics of the mechanism and the previous literature, yield the results according to the set goals [5, 6]. Mostly known that, in everyday life, human beings often involve much energy. Such as energy obtained from petroleum fossil energy, wind power and solar energy. However, the energy obtained from the solar cell system is influenced by temperature and radiation, producing electrical energy at the photovoltaic. Therefore, to ensure that the photovoltaic produces the highest energy at all times, regardless of external conditions, using a device called MPPT (tracking the maximum power point) to move the control mode to the most widely used stability but there are disadvantages due to chattering phenomenon. Therefore, these problems should be improved. This control is called AFSME (adaptive fuzzy sliding mode control) and compare with the SMC scroll mode controller to see the difference and use of P&O (Perturb & Observe) check this controller. All simulation results performed under MATLAB/Simulink and show the effectiveness of AFSMC control, confirming that the new method has developed energy, efficiency and production [7, 8]. The three-phase load connected to the three-level inverter, NPC, is proposed to create a gate signal for multi-level inverters. Both commands are developed and compared between the phase disposition pulse width modulation (PDPWM) and the space vector pulse width modulation (SVPWM). Verify the effectiveness of the introduced controller; it compared with the fuzzy logic controller. When simulated using MATLAB/Simulink program, analyse the results of these controls, shows that NPC has superior performance due to the quality of the output voltage for the entire adjustment index [9, 10]. This photovoltaic water pumping system consists of three main parts: PVG, dc-dc converter and dc motor with a centrifugal water pump. Has proposed a new MPPT algorithm using fuzzy logic and neural networks (ANN) to improve system performance. ANN is used to predict the best voltage of PVG under temperature conditions and solar radiation and use a fuzzy controller to control the boosting. The simulation results indicate that MPPT for ANN and fuzzy logic are performing well. This algorithm has proven to provide better performance: faster response times, more accurate and robust systems to change [11]. The energy paid by photovoltaic through the dc-dc energy converter by two factors: the radiation of the sun and the temperature. Therefore, improving the efficiency of the PV system requires the use of a mechanism to track the maximum power point (MPP). Traditional maximum power tracking methods such as observation and disruptive techniques cause problems in real MPP tracking. Therefore, intelligent systems, including fuzzy logic controllers (FLC), are used for the highest maximum point tracking system (MPPT).

A comparative study of standalone PV systems controlled by three techniques, consisting of traditionally based on observations and perturbation techniques, the other are intelligent based on fuzzy logic according to Mamdani and Takagi-Sugeno models. The investigations show that the fuzzy logic controllers provide the best results, and Takagi-Sugeno model presents the lower overshoot value [12, 13]. The overall performance of MPPT, mainly used in the application of PV, is analysed for interference and observation algorithms (P&O) and additional conductive media (INC). Results analysis for algorithms in the program MATLAB/Simulink for various changes in radiation, the research found that the efficiency of the P&O method is higher than that of INC. For the same efficiency, more intensive calculations should account for INC. Measurement of output power, the response of current and voltage of solar cells at constant values and variable radiation used as inputs for algorithms. The output waveform obtained from the simulation works according to the stated objectives [14]. The standalone photovoltaic system in terms of architectural design, building shape and dimension, then in terms of electricity. The block diagram presents the electrical design. The simulation verification principle is made for the solar panel matrix design, buck-dc dc converter by highlighting the member shape around the zero position, the ambiguous logical error, the FLC controller, is designed to guarantee the desired working condition of the maximum power point tracking function. The simulation results show the efficiency of the proposed solution to harvest the highest energy at different radiation levels [15, 16].

In the study of the efficacy of algorism, CS were examined to track the GMMP of the photovoltaic panel under PSC and compare with the P&O algorithm. The test in different cases of three cases of study. The PV module is used under PSC to evaluate the efficiency of the proposed CS algorithm. When test all cases, the tracking efficiency of the CS is higher than 99 % within 300-500ms. The improved CS algorithm can effectively manage PSC under different shading conditions while the P&O algorithm cannot handle the PSC of photovoltaic panels. The results also indicate that the energy traced by CS has very low static energy fluctuations compared to the P&O algorithm. Proving that SC is accurate, durable and efficient in energy efficiency for standalone PV systems [17]. The MPPT controller is the most commonly used control algorithm in the photovoltaic system because it is practical. When the MPPT control technique relates to artificial intelligence strategies, it can be improved. With less hassle than photovoltaic systems with fuzzy

logic controllers, it has been found that it works better than the P&O algorithm. From the test results, it is clear that the fuzzy method provides better performance compared to other MPPT techniques [18]. A single-phase five-level photovoltaic inverter topology for grid-connected PV systems with a novel pulse-width-modulated (PWM) control scheme, both reference signals that have the same compensation are equivalent to the amplitude of the triangle carrier signal that is used to generate the PWM signal for the switch. The inverter offers much less total harmonic distortion and can operate at near-unity power factor [19-22]. The cascaded H-bridge multilevel stacked solar photovoltaic modules for connecting to single or three-phase grids. The maximum power point tracking control applied to multi-level inverters in both single phase and three phases. Allowing the dc-link voltage to be controlled freely. For applications that connect to unbalanced three-phase grids. The experiment of a seven-level three-phase h-bridge inverter built using nine h-bridge modules. The simulation results and experiments confirm the correctness of the proposed method [23]. Phase angle detection of grid voltage is an important part of the control. For the synchronisation of the current injected by the inverter, the photovoltaic connected to the grid. Detecting the phase angle, frequency and amplitude of the grid voltage to generate a reference signal for the inverter to connect to that grid. Phase locking method (PLL) for single phase systems is to create orthogonal voltage systems using the second integrator (SOGI). Followed by the Park transformation of the quadratic component being forced to zero by fuzzy logic to provide fast detection and precise phase angle images. The test is used to separate the results and discuss the accuracy of the proposed algorithm [24, 25].

In this paper, study the tracking of the power of a photovoltaic panel to control a five-level stacked single-phase inverter switch connected to a fuzzy logic controller. The principle of controlling the maximum current amplitude of the photovoltaic multiplied by the sine signal per unit that used as a reference current compared to the grid current. Signal comparison with the PID controller allows the creation of five levels of PWM of cascade control of five-level inverter to connect single-phase grids. The system has been tested and evaluated using MATLAB/Simulink compared to the prototype created.

2. DESCRIPTION OF THE PROPOSED SCHEME

From the above mentioned, considering from Figure 1. The photovoltaic system that controls the maximum power by using P&O algorithms, which are basic controls that are not complicated and commonly used. For this research, a new concept introduced by applying fuzzy logic principles to control compensation current (i_{Comp}) obtained from the control of P&O methods to make the current ($*i_{Comp}$) more stable. For the control of semiconductor device switches (IGBT). Use the principle of detecting the voltage signal from the grid through low-frequency filtering (LPF) into the PLL process. To bring the time signal (ωt) together with the power angle (δ), to create a current that is a sinusoidal signal ($i_{S,pu}$) multiplied by the fuzzy current logic compensation ($*i_{Comp}$) to be a reference grid stream ($i_{S,ref}$) compared to the current that enters the grid into the current PID process ($i_{S,mod}$) to control PDPWM makes IGBT work according to conditions. In the multilevel cascade inverter, when connected to the grid, it will test the mechanism of the mechanism by adjusting the power angle to observe changes in the electricity supply to the grid. By simulation using MATLAB/Simulink program compare with the prototype created, which discussed in detail in each section.
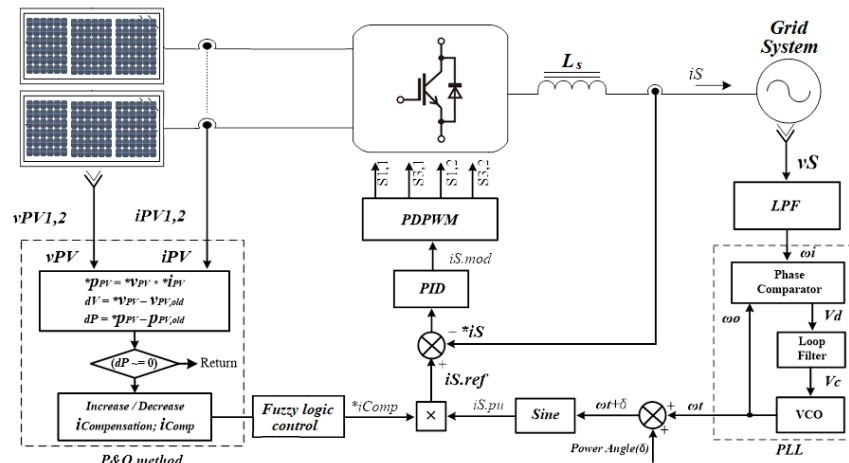

Figure 1. The structure of the power transmission control scheme.

2.1. Control of power distribution system

Consider from Figure 1, Fuzzy logic control scheme of cascade multi-level inverter control for photovoltaic grid-connected systems in this research. For the closed-loop feedback control system (PID), it must control the current system network amplitude. By bringing the real current in the network system back to the negative with the reference network stream through the PID controller to control the electricity in the network system concerning the power to the photovoltaic intensity, and must maintain the voltage at the capacitor to the highest voltage level. For creating one sinusoidal signal, it detects the signal from the voltage in the grid system through algorithm phase locked loop and combined with power angle, recreate the sinusoidal signal with the algorithm sine as one sine signal in one sine current variable. There is an initial angle corresponding to the voltage angle of the grid system to give the factor of power approaching one. From the above mentioned, the amplitude of the compensation current (i_{Comp}) change according to the relationship the amount of power. That is obtained from the photovoltaic in the maximum power tracking technique of the P&O method, through the creation of a condition of the fuzzy logic control, the system increase the order flow amplitude more when the intensity of the sunlight increases and similarly, when the light intensity decreases, the order flow reduced in the power of the photovoltaic. That recharged into the electrical network system varies according to the amplitude of the order flow. Creating a reference current grid system ($i_{S,ref}$) from in Figure 1, the reference current grid system, the product of bringing one sine signal ($i_{S,pu}$) that is a constant multiplied by the compensation current (i_{Comp}) according to the relationship of the maximum power tracking above. The result is a reference sine stream that is a pure sine signal that is equal to the amplitude of the current command controlling the current in the grid system. Will bring the reference grid current to the actual current in the grid system (*i_S) and enter the expected value for the gain control PID in order to control the current amplitude sine in modulation ($i_{S,mod}$) is the amplitude of one unit for modulation together with the PD triangle signal shown in Figure 2.

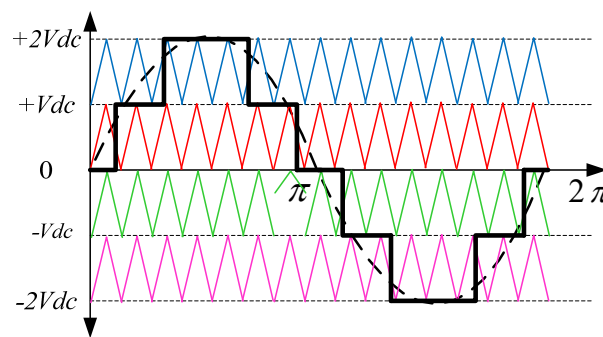Figure 2. Disposition pulse-width-modulated of cascade five-level inverter.

2.2. Perturb and observe; P&O method

For Figure 3, the maximum power tracking of the photovoltaic can write the working principle of the system. Find the maximum power by bringing current to compare with the previous current to maintain the voltage level at the capacitor and adjust the current value to the maximum power range according to the relationship of the power and photovoltaic intensity.

Considering the relationship graph, Figure 4, when the total power output is zero, the mean voltage and current are in the highest power point. However, on the other hand, when the sum of the power is not equal to zero, it is considered with the sum of the voltage in the range greater than or less than zero. If the total voltage is more significant than zero, indicates that in the calculation period, the direct voltage is higher than the maximum voltage.
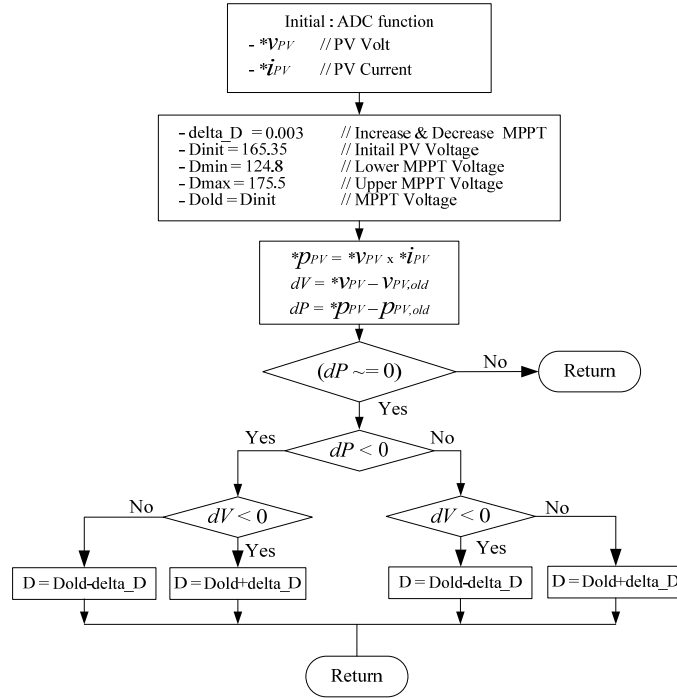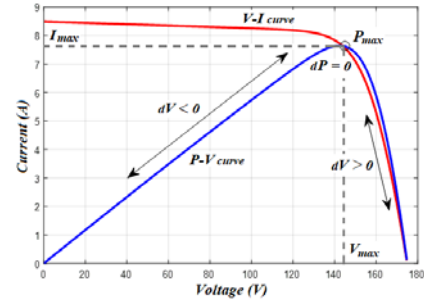
Figure 4. Maximum power tracking with P&O method.

Figure 3. Algorithm flow chart diagram

2.3. The fuzzy logic MPPT controller

A typical PID control is fixed feedback. Therefore cannot compensate for variations in process parameters and cannot adjust to changes in the environment. PID controlled systems do not respond to real changes and are quite fast in the system so that the system decreased at the set point. On the other hand, stimulation and observation (P&O) for tracking MPPT. The response results are not fast for rapid changes in temperature or radiation. Therefore the fuzzy control algorithm is capable of improving the tracking performance as compared with the classical methods for both linear and non-linear loads. Also, fuzzy logic is appropriate for non-linear control because it does not use a complex mathematical equation. Block diagram of the fuzzy logic controller shown in Figure 5, two fuzzy logic input variables are error power and error voltage. The fuzzy logic behaviour depends on the shape of the function and the basic rules.
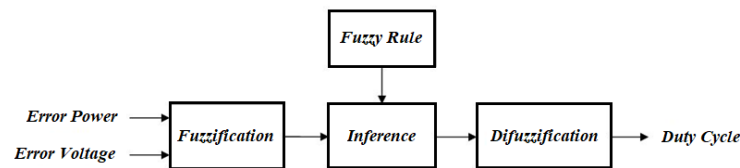

Figure 5. Fuzzy logic block diagram.

From Figure 5, to find the error of power and voltage, use the old value minus the new value to find the change of power and voltage which has the equation to find the change as the equation (1) and (2). Where $dE_{(k)}$ is the change rate of the error value at the time k, $E_{(k)}$ is the error value at the time k, $E_{(k-1)}$ is the error value at the time of k-1.

$$Error\ power_{(k)} = \frac{P_{(k)} - P_{(k-1)}}{I_{(k)} - I_{(k-1)}} \tag{1}$$

$$Error\ voltage_{(k)} = E_{(k)} - E_{(k-1)} \qquad (2)$$

The use of fuzzy logic to control the maximum power tracking is used to detect changes in the power of a photovoltaic and voltage change through processing in a fuzzy logic block. To create, calculate and compare as a duty cycle for controlling the voltage DC-DC boost converter circuit. The fuzzy part is the input variable for data changes in power and voltage and duty cycle values. Divided into 5 variables as follows: NB (Negative Big), NS (Negative Small), ZE (Zero), PS (Positive Small) and PB (Positive Big). In this research, the triangle used, as shown in Figure 6.
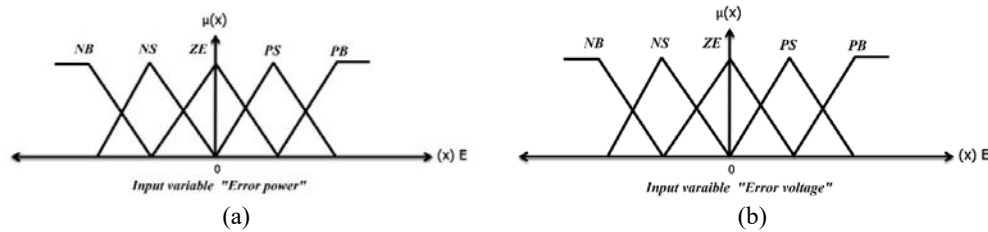

Figure 6. The triangle fuzzy logic characteristics.
(a) Input variable error power (b) Input variable error voltage

In terms of determining the working conditions of the Fuzzy Rule, it is necessary to use the expertise in that system. Design of output used for system control when error values are displayed, as shown in Table 1.

Table 1. The conditions of fuzzy logic.

Error Voltage/ Error Power	NB	NS	ZE	PS	PB
NB	NB	NS	ZE	PS	PB
NS	NB	NS	ZE	PS	PB
ZE	PB	PS	ZE	NS	NB
PS	PB	PS	ZE	NS	NB
PB	PB	PS	ZE	NS	NB

3. RESULTS AND DISCUSSION

The results of the simulation test using the program MATLAB/Simulink to compare with the generated prototype, the maximum power tracking of a photovoltaic to control a cascade five-level inverter a single-phase grid-connected with a fuzzy logic control. From the test of the work of the solar cell system, connect the converters with the grid, with the maximum power monitoring in average temperature and light intensity conditions, the test in the temperature and light intensity conditions suddenly reduced to view the results of the phenomena of parameters of the results as follows.

For Figure 7, the simulation of maximum power tracking in average temperature and light intensity conditions by setting the command flow (i_{Comp}). The voltage and current obtained from tracking the maximum power of photovoltaic from the simulation using the program MATLAB/Simulink and the power and current that is paid out from many inverters paid to the load and grid can be paid according to the conditions specified.
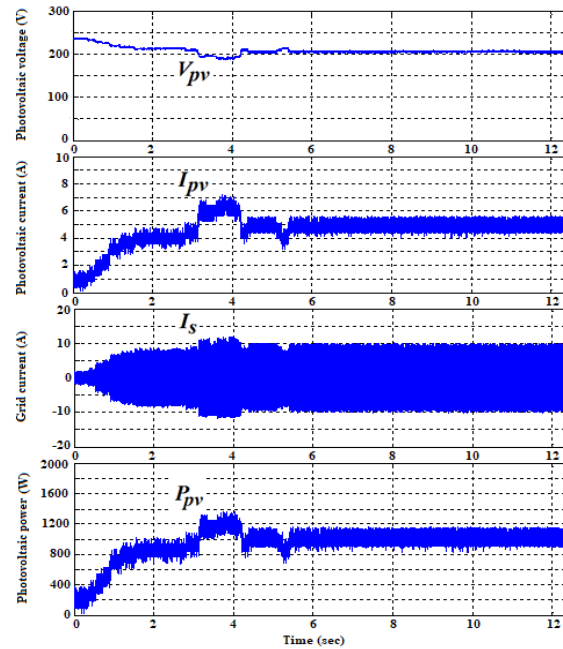
Figure 7. The simulation using the program MATLAB/Simulink.

For in Figure 8, the simulation at various light intensity consists of about 400, 600, 1000 W/m². It is found that when determining the same conditions as Figure 7, the maximum power tracing can be tracked, which proves that the fuzzy logic control model works according to the specified objectives.
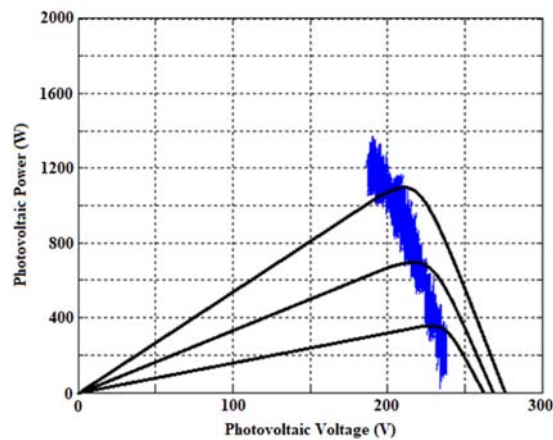

Figure 8. The relationship between voltage and maximum power tracking.

Similarly, when testing conditions in which light intensity and temperature changes suddenly, simulation results using the program MATLAB/Simulink. From observing the features of voltage and current changes and monitoring of the maximum power of the system, as well as the grid connections, the results are according to the terms set. Can be considered as Figure 9.
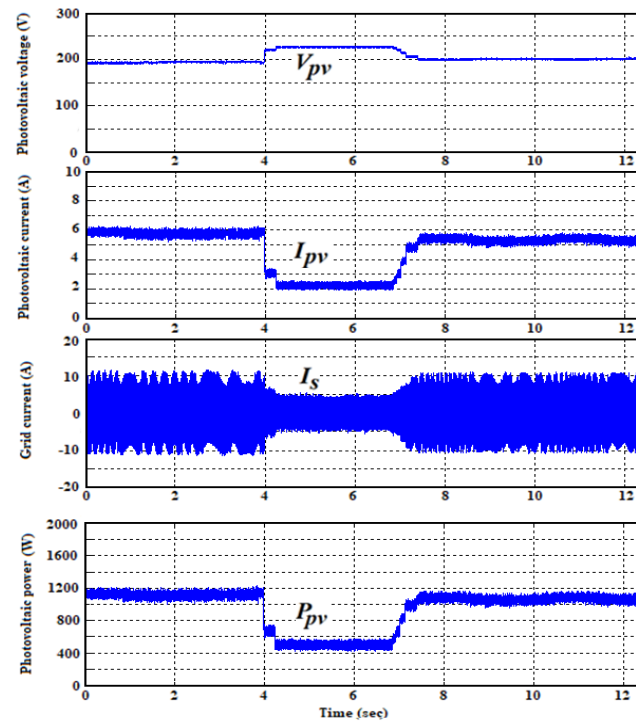
Figure 9. The light changes suddenly.

Based on Figure 9, the operation of the maximum photovoltaic power tracking system when a light incident occurred on the photovoltaic suddenly dropped naturally causing the power of the photovoltaic to decrease, resulting in the command current (i_{Comp}) has reduced amplitude. Moreover, the current and voltage and maximum power when the system is running at a sudden light intensity between 400, 1000 W/m² when the maximum power tracked. Show results, as shown in Figure 10.
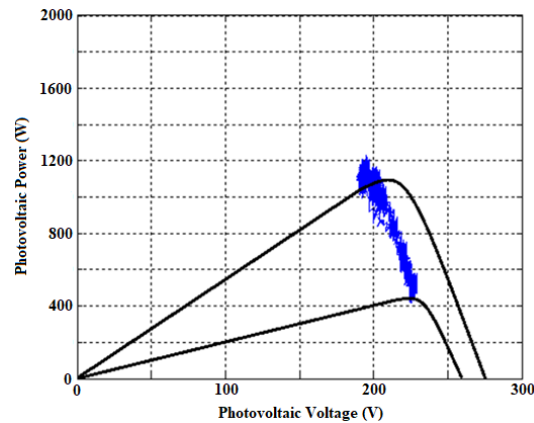

Figure 10. The relationship between voltage and power when a sudden change.

Figure 11, from the same conditions as the simulation results by the program MATLAB/Simulink. When testing the prototype built, it concluded that voltage, electricity, and tracking the maximum power of P&O when controlled by fuzzy logic as well as grid connections. The results are consistent with the simulation and can confirm that such principles applied to the desired purpose.
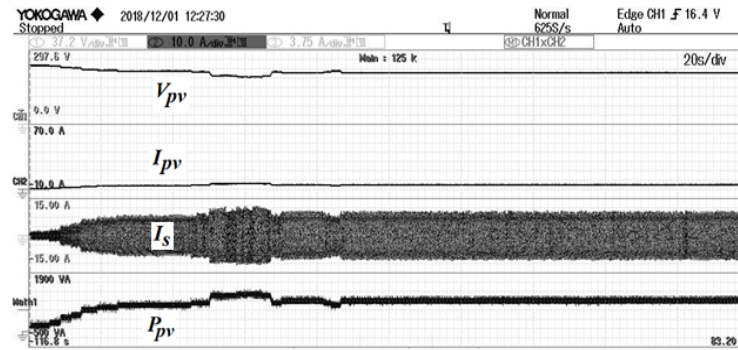
Figure 11. Light is tracking the radiation system of the prototype.

For Figure 12, similarly, when testing for the maximum power of the prototype to compare with the simulation using MATLAB/Simulink program according to the results shown above. The maximum power tracking results when the natural light intensity and an average temperature of the working mechanism respond to the specified conditions and can substantially confirm the accuracy between the simulation and the prototype as accurate as stated in principle.
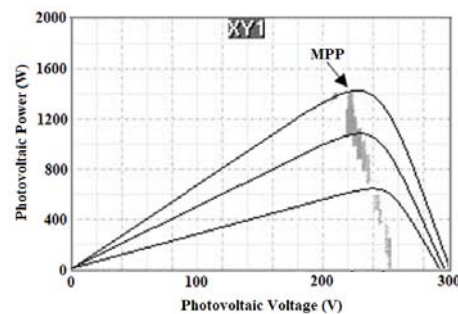

Figure 12. Maximum power test from the tracking system of the prototype.

Consider reversing, see Figure 9 and Figure 10 in conditions where the light intensity and temperature changes suddenly due to cloud cover and other factors. When comparing the results with the same conditions, the results are consistent and in the same direction, as shown in Figure 13 and Figure 14. Which confirms that the research targeted to prove the maximum power tracking principle of the control mechanism is a feature that makes the power flowing into the nonlinear load and the grid supply controlled due to the power supplied by stable photovoltaic.
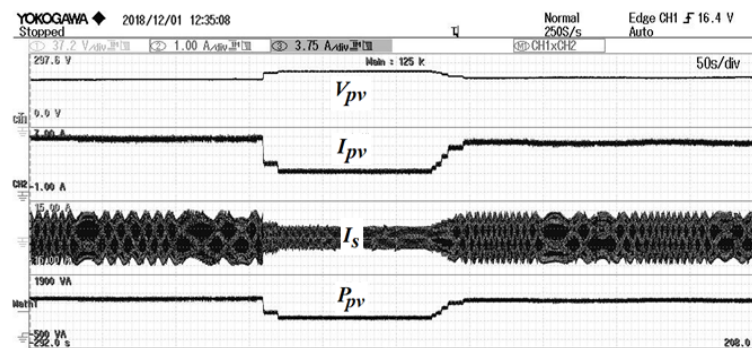

Figure 13. Parameter values when the light changes suddenly on the prototype.
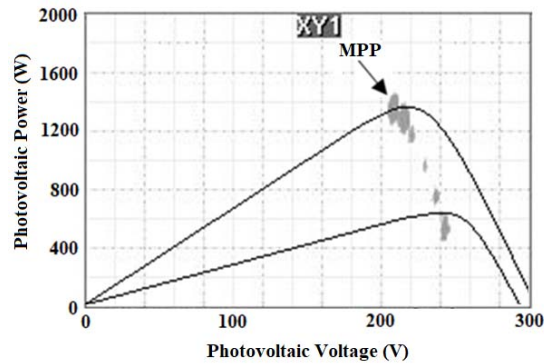
Figure 14. Maximum power test from the tracking system.

This research, when testing the prototype machine by supplying excess energy to the grid to test the current control mechanism, power angle control and compensation mechanism, harmonic, both simulated with MATLAB/Simulink program compare with the prototype. The result is as shown in the Figure. 15 (a) and (b) for the simulation and Figure 16 (a) and (b) from both figure, it can be seen that the waveforms supplied to the grid are close to the sine wave and phase angle from the grid voltage because the system is in inverter mode. Moreover, the harmonic spectrum of the current paid to the grid has total harmonic distortion (THD) reduced.
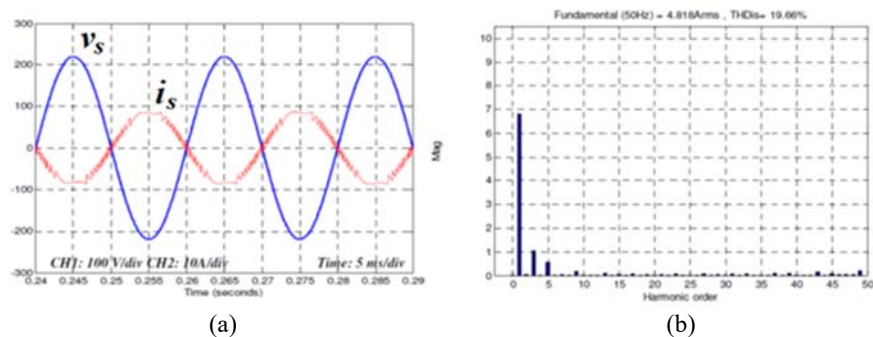

Figure 15. The simulation of harmonic current compensation
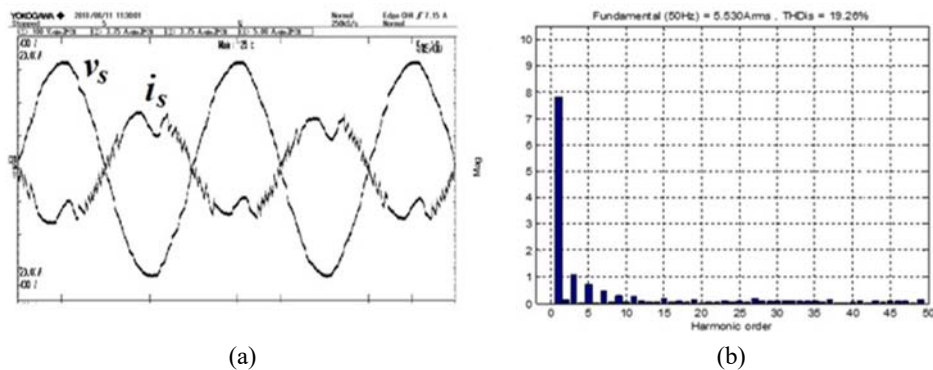(a) voltage and current supplying to grid-connection (b) Harmonic spectrum

Figure 16. The experiment of harmonic current compensation on the prototype.
(a) voltage and current supplying excess energy to the grid (b) Harmonic spectrum

4. CONCLUSION

Simulation testing with the program to compare with the prototype created for tracking the maximum power of the solar cells to control the five-level inverter type cascade, connect the single-phase grid system controlled by using fuzzy logic. The proposed system can operate according to the specified conditions. It is an indication that the proposed system can use the fuzzy logic principle to control the maximum power tracking conditions of the P&O method. When the radiation light intensity changes suddenly, the maximum power of the photovoltaic can be tracked. When applying the principle of maximum current amplitude control of the photovoltaic multiplied by a sine signal per unit that comes from the power angle control as a reference current compared to the current in the system connected to the grid. Which is a comparison signal of difference through the PID controller to control the operation of the inverter, to connect the grid by comparing results between simulation and prototype. Found that the system can send the remaining energy back to the grid system and can control the harmonic in the system can work at energy factors near unity. From the prototype which can be seen that the mechanisms and prototypes are applied in the home and can reduce the cost of using electricity in an extensive grid system, and the researchers expect to develop more effective improvements in the future.

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